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FLAIL CONDITIONING of ALFALFA HAY

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INTRODUCTION

The value of the forage crusher as a device to increase the field drying rate of forages has been recognized. It has become common practice to condition the forage crop soon after mowing in an attempt to reduce the field drying time and weather risk. Crushers and crimpers were the devices employed for this purpose and proved to be valuable aids in making higher quality forage than was, as a general rule, previously possible without conditioning.

New demands for methods to decrease the field drying time still further have focused attention on the use of flail forage harvesters as forage conditioners. Since, these machines were manufactured for an entirely different function it would not be expected that they perform as well as a flail machine designed for forage conditioning.

It is helpful to analyze the field drying process to see what is actually needed in the way of a conditioning machine. According to many sources of research, the rate of drying of the leaves of alfalfa exceeds the drying rate of the stalk. This is, in itself, one of the main reasons for conditioning at the time of cutting. In an unconditioned stalk the moisture must be transferred from within, through a relatively thick layer, during drying. According to heat and mass transfer principles, the shorter the distance through which the moisture must diffuse, the greater will be the moisture diffusion rate. The distance through which the moisture must diffuse is reduced by conditioning the forage stem in such a way as to split the stem longitudinally. Thus, more of the stem volume is exposed to the drying medium as well as reducing the distance the moisture must travel. As a result of the reduced distance the moisture must travel, the time required for drying is also reduced. Cutting the forage stem transversely, without crushing, does not appreciably increase the overall drying rate due to the negligible amount of additional area exposed to the drying medium. This does not hold true as infinitesimal-sized pieces are approached. Short pieces are not practical because of an increased tendency for them to become matted together, thus, restricting the flow of air through the material and reducing the drying rate. Also, the smaller the segments of forage the greater the tendency for field losses.

What is needed in the way of a conditioner is a machine which will direct-cut the forage and split the stem longitudinally, but not transversely, rather than just crack the stem to a limited degree. The larger stems should be split more times than the smaller stems to get a more uniform rate of drying throughout the stalk. This means that the leaves, which already have the most rapid rate of drying of any part of the stalk, should remain intact and should not be conditioned. It is also desirable to have the stems exposed to the sun with the leaves protected and leave the forage in a fluffy condition on the ground.

Daum (3) has shown that the attachment of alfalfa leaves to the stem is influenced by the moisture content of the total stalk with the force necessary to remove the leaf from the stem decreasing rapidly below a stalk moisture content of approximately 40 percent, wet basis. This same general relationship was shown to exist for all stages of bloom from prebloom through ¾ bloom. This would indicate that alfalfa should be packaged at or above 40 percent moisture content or, if handled loose, in storage by the time a 40 percent moisture content is achieved if the maximum amount of nutrients are to be harvested. The force measurements were made on unconditioned alfalfa; therefore the critical level would probably become approximately 30 to 35 percent for conditioned stalks. Since the leaf attachment is affected by the moisture content at the point of attachment rather than the overall moisture content, conditioning would result in an overall moisture reduction while virtually not affecting the moisture content at the leaf attachment, as conditioning tends to affect the larger portion of the stems of the plant rather than the smaller portion of the stems as would be located at the point of leaf attachment.

Casselman and Fincham (2) compared the field drying rates of alfalfa hay which had been flail-cut, mowed and crimped, and mowed. The flail-cut material, which was placed in windrows by the flail unit, dried to 20 percent moisture content, wet basis, in 28 hours, whereas the crimped alfalfa required 53 hours and the conventional about 77 hours.

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Boyd (1) conducted field tests to determine field drying rates and field losses of alfalfa-clover and timothy-brome hay which had been conditioned with a crimper, a crusher, and a flail-type forage harvester. Results indicated that flailed material dried at a greater rate than the other conditioned materials. He also reported pickup losses of approximately 7 percent of the total yield for unconditioned alfalfa, 11 percent for crushed and crimped, and 14 percent for the flailed material.

Several other unpublished sources reported harvesting losses of one-third or more of the total crop when flail conditioning was utilized.

DESCRIPTION OF FIELD MACHINES

A flail-type forage harvester and a crusher were used to condition the alfalfa hay used in this experiment. A conventional mower was used to cut the material which was crushed. A 5-bar rake was used for raking the hay.

The flail unit consisted of a horizontal shaft, perpendicular to the direction of travel, on which are suspended a number of cup-shaped flails which are hinged and can rotate in the plane parallel with the direction of travel. The hood generally used to convey cut material into a wagon, or other conveying device, was removed and replaced with a short hood to direct the material back on the ground in a swath. The width of cut was five feet. A model 35 Ferguson tractor was used to power the flail unit.

The crusher consisted of one smooth, rubber roll and one steel, fluted roll.

TEST PROCEDURES

Samples from the three methods compared—mowed, mowed and crushed, and direct-cut flailed—were taken within minutes of each other. The samples were placed on trays which consisted of twine string loosely woven on 6-foot square wooden frames. The forage was permitted to attain a more natural contact with the ground by the use of the loosely woven string than would be attained with tight or rigid netting. The samples were weighed periodically with a scale suspended from a tripod.

The moisture content of the alfalfa-brome forage at the time of harvest was determined by clipping material and immediately placing it in a forced-air oven for 72 hours at 212 degrees F. Moisture contents during field drying were determined from the original moisture content at the time of cutting and the weights during the field drying process.

Two replicates were conducted for each test condition. The results plotted in Figures 1, 2, and 3 are an average of the two replicates.

The same field was used for three cuttings of alfalfa with the first cutting consisting of three-fourths alfalfa and one-fourth bromegrass. A second field of third cutting alfalfa was used for tests to determine the effect of various flail rotor and ground speeds on the drying rate.

FIELD DRYING RATES

The first cutting of alfalfa at 5 percent bloom, was made on 24 May 1961 at 12:30 P.M., DST. The second half of the same field was cut on 25 May 1961 at 9:15 A.M. The first day was a bright, sunshiny day and the second was hazy with partially cloudy conditions. The climatological data are given in Table 1. The solar and sky radiation give an indication of the drying potential of that day. The wind velocity and daily evaporation rate are also an indication of the drying rates. The tests on the first cutting alfalfa were concluded at 10:00 P.M. on 25 May when it started to rain.

The flailed material gained more moisture overnight than the crushed material, but lost it faster the next morning, as is shown by the 7:40 P.M., 6:40 A.M., and 9:40 A.M. moisture contents in Figure 1, which shows the drying rates for both halves of the field. The flailed material was one-half percent drier at 9:40 A.M. than it had been at 7:40 P.M. the previous day, whereas the crushed and conventional material were at the same moisture content as they had been at the 7:40 P.M. weighing. The effect of cutting while dew is still present is illustrated by comparing the hay cut at 12:30 P.M. with that cut at 9:15 A.M. the next day. The hay cut at 12:30 P.M. required 27 hours to dry to 40 percent, but the material cut at 9:15 A.M. required only 10 hours to dry to 40 percent. Similar results were obtained with the crushed and conventional treatments even though the first drying day was very similar, in drying potential, to the second day. In every test conducted the flailed material dried the fastest of the three conditioning methods.

The second cutting, at 10 percent bloom, was cut on 10 July 1961 at 10:00 A.M., DST. The samples, used to determine drying rates, were raked at 10:00 A.M. of the second day to simulate actual practices. The raking was done by hand in an attempt to simulate machine raking. The climatological data are given in Table 1 and show that the drying potential, as measured by solar and sky radiation, evaporation, and wind velocity, was not as great for the second cutting as it had been for the first cutting. Other factors which must be considered are the soil moisture content and the amount of forage per unit area. For the second cutting the soil moisture was lower and the

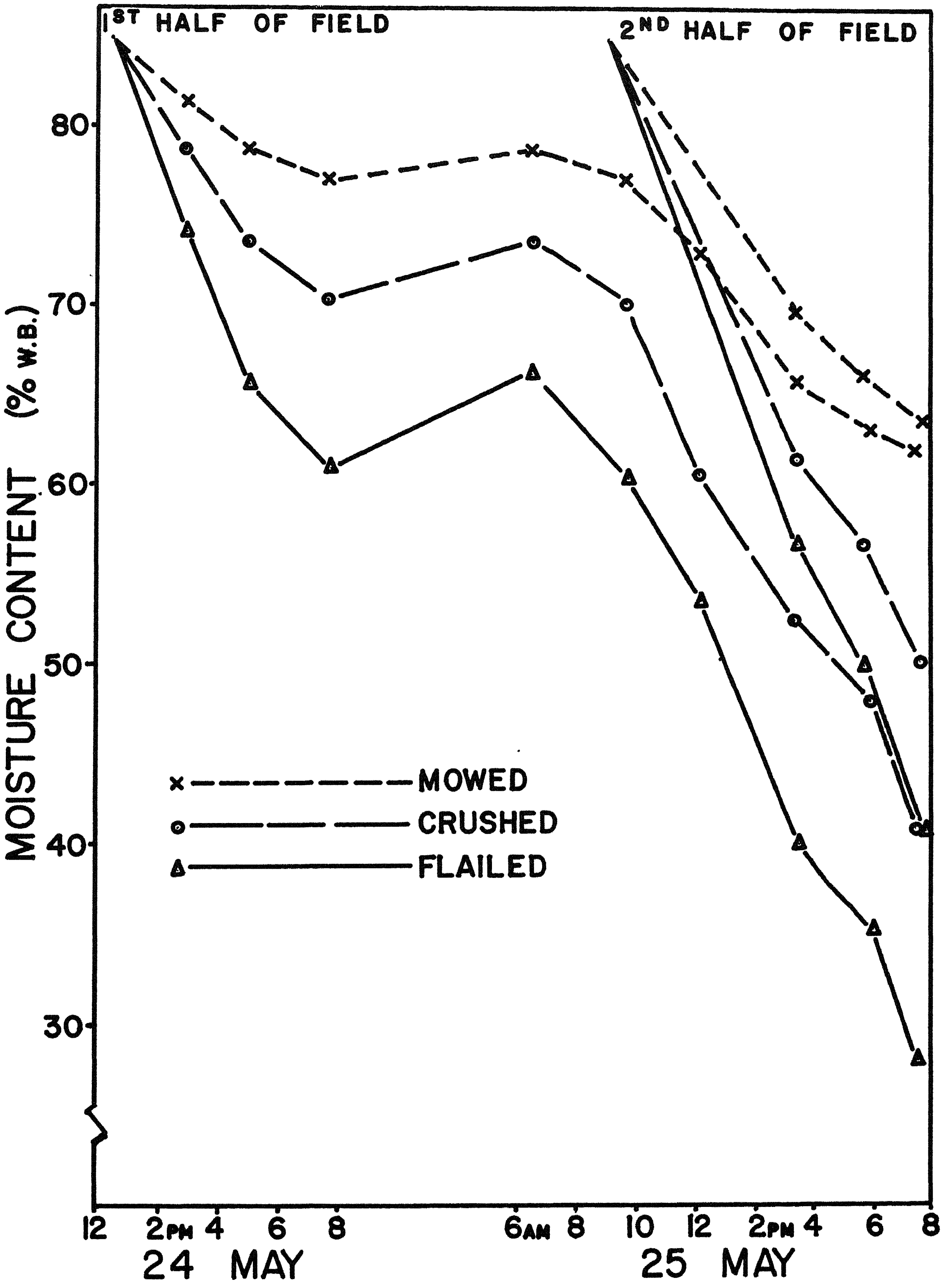

FIGURE I. CHANGES IN MOISTURE CONTENT DURING FIELD DRYING OF 1ST CUTTING ALFALFA amount of material on the ground was less, resulting in overall drying characteristics of a similar nature between the first and second cuttings. The drying rates for the second cutting alfalfa are shown in Figure 2.

Losses were checked on the second cutting by removing all material remaining after the alfalfa was baled. The remaining stubble was clipped to a two inch height with a lawn mower and a vacuum cleaner was used to collect the material while the dew was still present, to cut down the amount of fine material which would develop if the leaf losses were handled while dry. The collected material was hand sieved to separate the soil, picked up by the vacuum cleaner, from the alfalfa. The losses determined included raking, baling, and stubble losses. As this was the same field that was used for the first cutting and the same portion of the field was flailed or crushed as for the first cutting, the losses reported would include some losses from the first cutting. The loss per acre for the flailed alfalfa amounted to 14.1 percent of the total yield and the crushed alfalfa loss was 11.6 percent of the yield. These values were the average of three replicates with each replicate taken from a 36 square foot area.

The third cutting, at 5 percent bloom, was cut on 21 August 1961 at 10:30 A.M. The three acre field was split in half with one-half flailed and the other half mowed and crushed. As shown in the climatological data, Table 1, the first two days after cutting were cloudy, rainy days, very unsatisfactory for field curing alfalfa, during which approximately a six percent reduction occurred in the moisture content of all three treatments. The alfalfa was not placed on the drying frames for this portion of the experiment as the only information desired was the harvested yield. Moisture contents were determined by sampling the material in the field at various locations and oven drying the samples to determine the moisture content. Fifty hours after cutting, the alfalfa in the field was raked to get it up out of the stubble.

The alfalfa was baled on the fourth day at 2:45 P.M. when the crushed hay was at a moisture content of 41 percent, while the flailed hay was down to 36 percent. The harvested yield was determined by weighing the bales and correcting the weights to 20 percent moisture. The crushed alfalfa yielded 1710 pounds per acre and the flailed alfalfa yielded 1685 pounds per acre. This amounted to a difference of approximately 1.5 percent of the total yield between flailing and crushing.

In an attempt to determine the effect of various ground and rotor speeds on the drying rate, third cutting alfalfa was flail-cut on 8 September at various ground and rotor speeds and compared with crushed alfalfa in regard to drying rates. Since the extent of conditioning on the forage depends on the ground speed and flail rotor speed, a ratio of the flail tip velocity to the ground speed, both in feet per minute, will be used to designate the severity of the flail conditioning. This "severity index" will be directly related to the amount of work done on the alfalfa stalks; in other words, the more work done to the alfalfa stalk, the higher will be the index. The optimum index for flail machines would probably vary with machines from different manufacturers.

As the flail speed is increased, in a given field, at a fixed ground speed the amount of conditioning performed on the alfalfa stalk is also increased, as is the severity index. As the ground speed is increased, other factors held constant, there will be more material passing through the machine per unit time and less conditioning will result, with a corresponding decrease in the severity index.

The amount of forage growth would be a factor in addition to the ground and rotor speeds which would influence the severity index. Another factor which is not taken into consideration in the severity index is the velocity of the alfalfa as it leaves the machine. This could be quite important in a machine not properly designed for hay conditioning as the velocity of the hay would probably determine, to some extent, the manner in which the hay is placed on the ground.

The rotor and ground speeds were determined when the unit was under full load for any given condition. Figure 3 shows the drying rates of alfalfa flailed at several different severity indices in comparison with crushed alfalfa. Each point, as plotted, is an average of two replicates. Table 1 shows the climatological data. As is shown by Figure 3, it is important to select a proper ground and rotor speed to be used for conditioning. Indices of 20, 28, and 44 resulted in drying rates which were greater than the drying rate of crushed hay, while the indices of 120 and 140 resulted in similar drying rates which were less than the drying rate obtained by crushing. An index of 20 resulted in hay at 24.9 percent moisture, whereas the next higher index of 28 resulted in hay at 30.8 percent, at the end of the third day of drying. The index of 20 is actually an average of the indices of 19.4 and 20.6. The index of 19.4 resulted in a drying rate which was slightly less than the drying rate for the 20.6 index. This would indicate that the optimum amount of conditioning had been reached at an index of approximately 20. The optimum amount of conditioning means that the amount and type of conditioning done by this machine had reached an optimum, and it does not

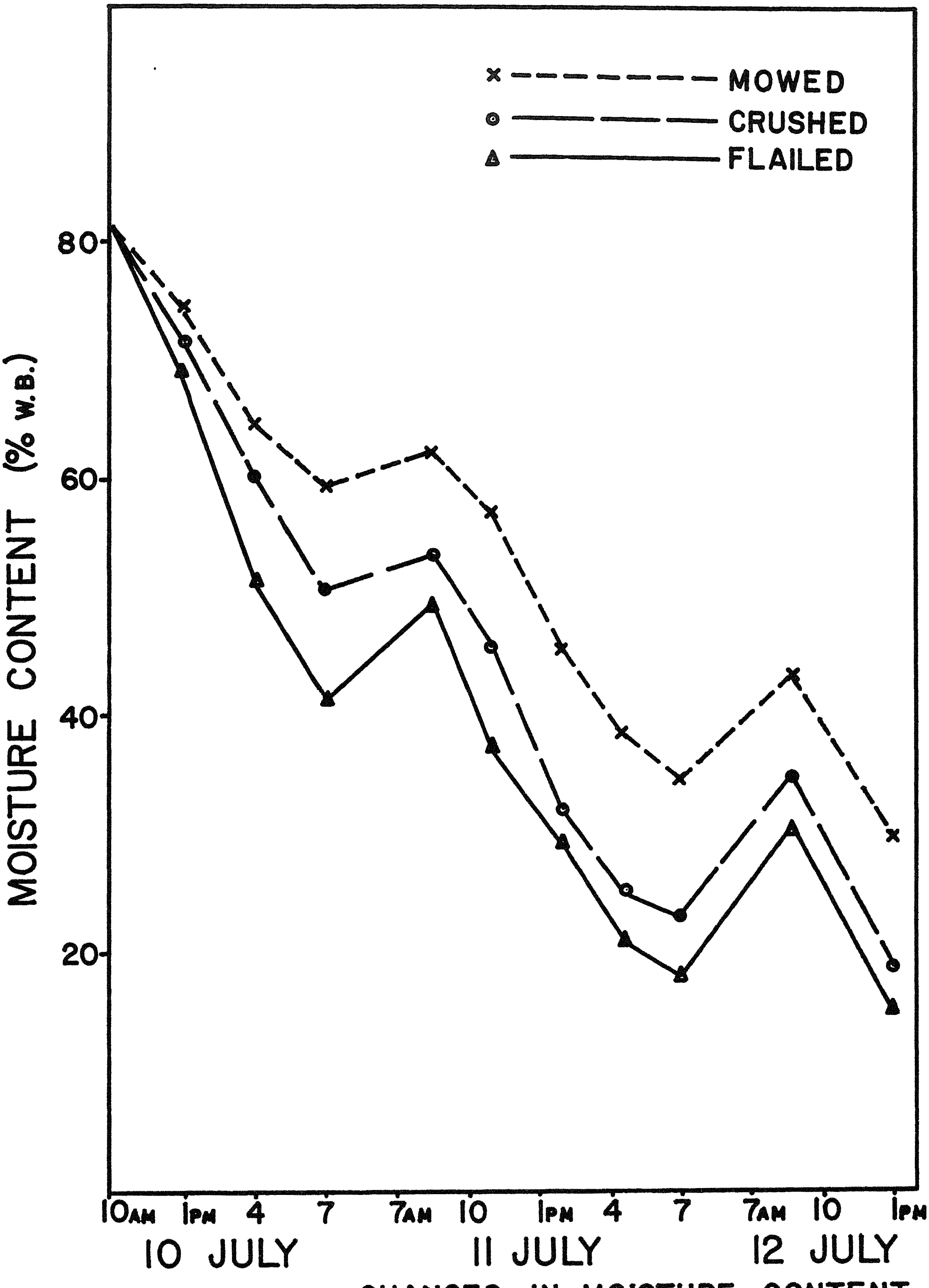

FIGURE 2. CHANGES IN MOISTURE CONTENT DURING FIELD DRYING OF 2ND CUTTING ALFALFA

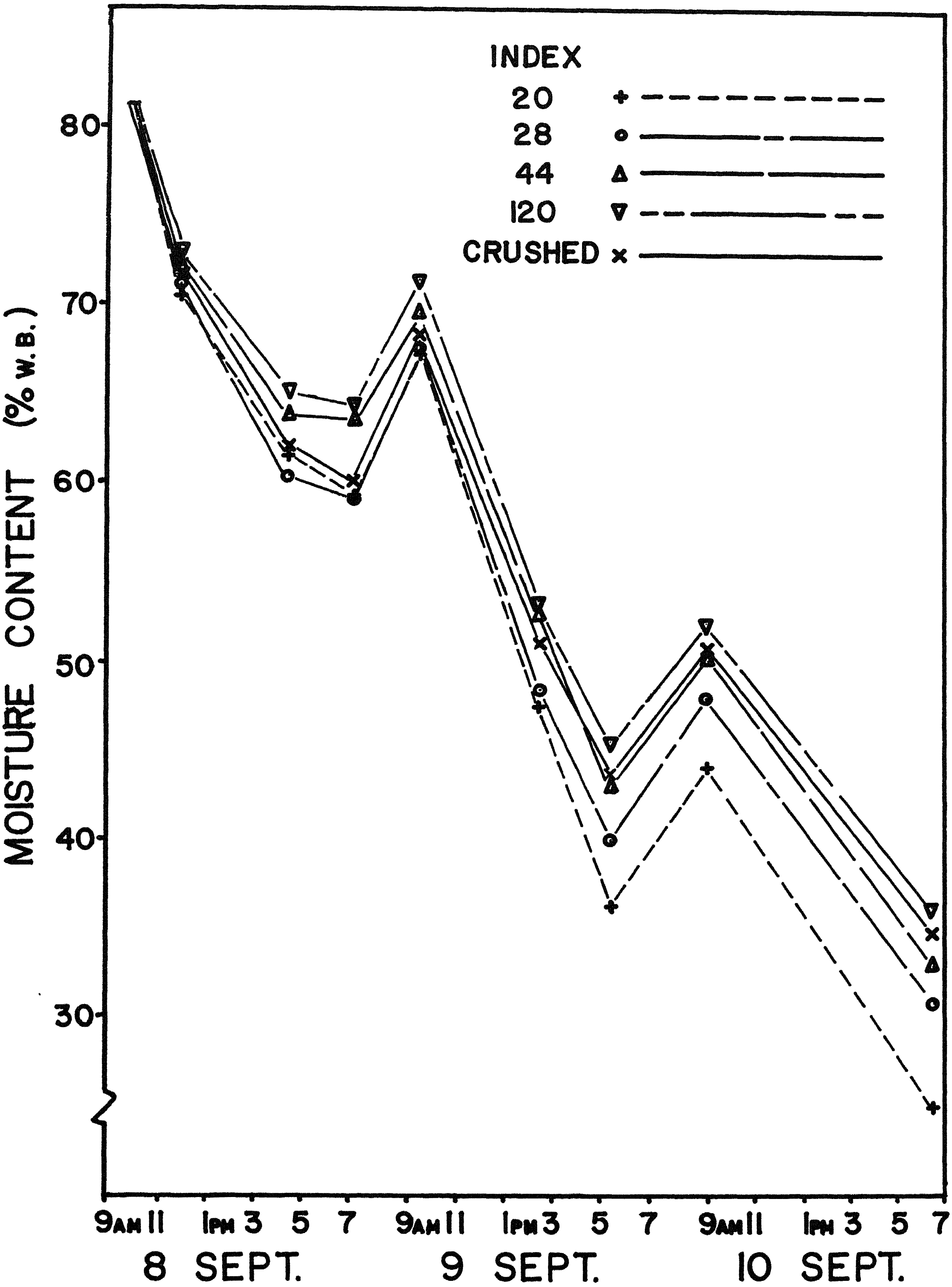

FIGURE 3. CHANGES IN MOISTURE CONTENT DURING FIELD DRYING OF 3RD CUTTING ALFALFA

mean that the maximum amount of the most desirable type of conditioning had been performed.

SUMMARY

The major drawback in the use of the flail machine for conditioning forage is the fact that care must be exercised in selecting the proper rotor speed and machine ground speed. As a general rule, it is better to travel at a high rate of speed and keep the rotor speed low. Unfortunately, this is just opposite the procedure used by most workers when they are testing a new piece of machinery in the field. If the ground speed is too slow, the forage will be conditioned to a point such that many fine pieces result. This is probably the major cause of the excessive losses reported by some research workers. An additional loss of 2½ percent of the crop due to flailing rather than crushing is an insignificant price to pay for the decreased weather exposure and the decrease in the amount of coarse, sharp material which is possible by flail conditioning that follows good management practices.

It is possible to direct-cut with the flail unit and do less conditioning to the forage stalks than is done with a crusher. This is done by reducing the rotor speed in comparison with the ground speed, resulting in a very ragged appearance of the stubble in the field and a reduced drying rate due to the lack of sufficient conditioning. Therefore, care must be taken to prevent under-conditioning as well as over-conditioning. After a round or two in the hay field, the operator of a flail conditioner can determine the proper rotor and ground speeds by a visual inspection of the conditioned material to ascertain the length of cut.

The regrowth characteristics were visually checked and there were not any apparent differences between the flail-cut or the mowed areas of the field.

CONCLUSIONS

1. Flail conditioning is an effective way to increase field drying rates of alfalfa.

2. Losses due to flail conditioning were approximately 1½ to 2½ percent of the total yield greater than the losses due to crushing.

3. The optimum severity index obtained was 20, higher values resulted in a decreased field drying rate.

4. Regrowth of the alfalfa was not affected by the method of conditioning.

5. Good management practices must be followed to obtain satisfactory results with the flail conditioner.

BIBLIOGRAPHY

1. Boyd, M. M. "Hay Conditioning Methods Compared." Agricultural Engineering, Vol. 40, pp. 664, November, 1959.

2. Casselman, T. W. and Fincham, Robert C. "How Effective are Hay Conditioners?" Iowa Farm Science, Vol. 15, pp. 3-6, November-December, 1960.

3. Daum, Donald R. "A Study of the Leaf Shattering of Hay Caused by Mechanical Handling." Pennsylvania State University, 1958.

4. Hall, Glenn E. "Flail Harvester–Mower, Crusher, Rake?" Dairy Science Mimeograph Series 8 M M, Ohio Agricultural Experiment Station, Wooster, Ohio, August, 1960.

TABLE 1.–Climatological Data

Time	Temperature Degrees Fahrenheit	Relative Humidity Percent	Temperature Degrees Fahrenheit	Relative Humidity Percent	Temperature Degrees Fahrenheit	Relative Humidity Percent	Temperature Degrees Fahrenheit	Relative Humidity Percent
	24 May	24 May	10 July	10 July	21 Aug.	21 Aug.	8 Sept.	8 Sept.
8:00 A.M.	50	70	-----	-----	63	99	56	97
10:00	65	60	67	61	65	99	68	62
12:00 Noon	71	41	75	37	69	95	76	48
2:00 P.M.	75	42	78	34	73	74	78	44
4:00	81	37	79	34	73	69	81	42
6:00	70	44	79	36	70	73	81	43
8:00	56	58	72	40	65	82	75	75
10:00	48	74			64	94	66	97
12:00 Mid.	47	78			63	95	60	97
	25 May	25 May			22 Aug.	22 Aug.	9 Sept.	9 Sept.
2:00 A.M.	47	76			63	95	58	97
4:00	44	78			63	96	55	97
6:00	43	81	11 July	11 July	62	98	54	98
8:00	56	72	60	90	62	96	55	98
10:00	68	58	70	75	64	96	62	98
12:00 Noon	75	46	78	55	67	97	76	55
2:00 P.M.	73	44	82	42	74	64	81	40
4:00	73	44	84	39	76	58	82	31
6:00	71	44	80	45	75	73	85	32
8:00	63	46	75	52	67	91	72	52
10:00			67	64	63	95	65	86
12:00 Mid.					63	95	61	90
					23 Aug.	23 Aug.	10 Sept.	10 Sept.
2:00 A.M.					62	95	58	95
4:00					61	95	55	96
6:00			12 July	12 July	59	95	54	96
8:00			64	92	65	94	56	96
10:00			72	63	72	84	70	75
12:00 Noon			78	46	70	84	80	50
2:00 P.M.			80	39	74	68	86	40
4:00			82	37	80	60	89	35
6:00			78	44	76	80	87	40

	24 May	25 May	10 July	11 July	12 July	21 Aug.	22 Aug.	23 Aug.	24 Aug.	8 Sept.	9 Sept.	10 Sept.
Solar and Sky Radiation $\left(\frac{\text{gm cal}}{\text{cm}^2\text{day}}\right)$	726	680	717	574	474	325	366	354	412	549	533	529
Wind Velocity (mile/day)	103	192	70	56	55	62	36	22	35	35	20	20
Evaporation (inches/day)	.27	.33	.29	.22	.14	.20	.08	.09	.13	.18	.17	.16

TABLE 2.–Ground and Rotor Speeds for Third Cutting Alfalfa

	Indices						
	19.4	20	20.6	28	44	120	140
Ground Speed (mph)	2.0	3.5	2.75	2.0	1.6	.75	.88
Rotor Speed (rpm)	550	1000	800	800	1000	1500	1500
Tractor Gear	5	5	5	4	3	2	1

TABLE 3.–Yields and Losses of Alfalfa at 20 Percent Moisture

	1st Cutting		2nd Cutting		3rd Cutting	
	Flailed	Crushed	Flailed	Crushed	Flailed	Crushed
Total Yield (lb/A)	2500	2500	2200	2200		
Harvesting Loss (lb/A)			312	255		
Harvested Yield (lb/A)			1888	1945	1685	1710